Rogun Alert Coalition

What is more efficient than "the tallest dam in the world"?

(Analysis of Alternatives for the Completion of Rogun HPP Project)

RIVERS WITHOUT BOUNDARIES

Rivers without Boundaries International Coalition

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Introduction

For five decades, the completion of the Rogun hydropower plant with a capacity of almost 4 GW and a dam height of 335 meters has been considered by many as the optimal solution to Tajikistan's energy supply problems, but its implementation faces significant environmental, geological, socio-economic, humanitarian, and financial challenges. Even if its completion proceeds according to plan, it will be completed only in 2039, and in reality it may take much longer[1]. One of the recurrent planning mistakes made each time this project has been revived and reviewed is the lack of assessment of alternative solutions to the project's challenges. This note discusses some of the key factors, opportunities and risks that should now be considered during project finalization to ensure that better decisions are made on the basis of more complete and reliable information.

The draft Environmental and Social Impact Assessment (ESIA) of the Rogun HPP project, disclosed in December 2023[2], completely lacks an analysis of alternatives based on up-to-date data. The ESIA merely cites an outdated analysis done more than 10 years ago, although significant changes have occurred since then in technology, natural processes, economics, and the body of scientific knowledge.

We are convinced that it is impossible to make a responsible decision on whether to complete the Rogun HPP project on the Vakhsh River in Tajikistan - and if so, what the optimal option is – without comparing the available development alternatives and their associated impacts on nature and society. Without this, it will not be possible to choose the optimal option for project completion, which implies avoiding and mitigating, as well as reducing the probability of occurrence of potential negative consequences, as prescribed in all modern environmental and social policy frameworks of international development banks.

To illustrate this need, we have considered a variety of alternatives for the completion of the Rogun HPP and the development of Tajikistan's energy system in light of the factors that need to be considered when choosing a development path. These factors include revolutionary changes in energy efficiency and economic feasibility of industrial use of renewable energy (solar and wind generation), growing economic risks of establishing the HPP, natural risks in light of accelerating climate change, humanitarian risks associated with human resettlement, socio-economic and environmental impacts downstream.

We argue that if the decision is made to fully complete the Rogun HPP according to the maximum dam height option (this is the option that is now being considered by development banks without alternatives), the acute problems that it was created to overcome will not be solved any time soon. In particular, electricity blackouts in Tajikistan will not stop and may persist at least until 2037. Further, the likelihood of blackouts will depend on the conflict between the extensive power export obligations

[1] "*70% experienced a cost overrun, and more than 80% of projects experienced time overruns…*" Baurzhan, S.; Jenkins, G.P.; Olasehinde-Williams, G.O. The Economic Performance of Hydropower Dams Supported by the World Bank Group, 1975–2015. Energies 2021, 14, 2673. https://doi.org/10.3390/en14092673

[2] All Rogun HPP Project ESIA documents http://www.energyprojects.tj/index.php/ru/rogunskaya-ges/eko-sots-instrument?limitstart=0 and their English versions http://www.energyprojects.tj/index.php/en/rogun-hpp/eko-sots-instrument

of the Rogun hydropower plant and fluctuations in the water availability of the Vakhsh River in winter.

At the same time, as our preliminary calculations of alternative scenarios for project implementation show, the combination of solar generation development with the completion of Rogun HPP with a smaller dam may make it possible to fully cover the winter energy deficit in Tajikistan by 2030-2031. Diversification of energy sources within the unified energy system of the country will also significantly reduce climate change risks for the energy sector and the economy.

Acknowledgements

The Rivers without Boundaries Coalition is deeply grateful to Pippa Gallop (CEE Bankwatch) and three anonymous reviewers from the countries of Central Asia for providing valuable advice that helped to improve this report.

Why an analysis of alternative scenarios for the Rogun HPP project?

Electricity exports. Whether neighboring countries will need to buy electricity from Tajikistan depends on the price and timing of large-scale electricity supplies. All neighboring countries have ambitious plans to develop power generation on their territory and even to produce "green energy" for export to the European Union.[3]

The window of opportunity for Tajikistan to supply energy from renewable sources to its neighbors at competitive prices may close within the next 5-7 years - long before the Rogun HPP is completed in the maximum dam height variant. In addition, the cost of Rogun's electricity will be more expensive than that produced by solar photovoltaics (SPP) and wind (WPP) power plants. If Tajikistan intends to become an electricity exporter to its neighbors, it needs to develop SPP and WPP in addition to the maneuverable capacities of the already built HPPs, rather than creating new giant reservoirs. Therefore, when analyzing the competitiveness of electricity generated at Rogun HPP in the future, it is necessary to take into account the ambitious plans of neighboring countries to build SPPs, WPPs, hydropower, gas and coal-fired TPPs, and nuclear generation, to the extent that such plans are realistic. Plans of Central Asian countries to increase the purchase of pipeline gas from Russia, the development of own fossil fuel production, fossil-based energy and fuel exports, including to such a potential consumer of Rogun's electricity as Pakistan, may also influence regional demand for electricity, even though they are incompatible with decarbonisation.

Decarbonization of the region. Even if, due to political factors, Uzbekistan, Kazakhstan, and Pakistan conclude long-term contracts with Tajikistan to supply energy from the Rogun HPP, this will not lead to significant timely reduction in greenhouse gases of the Central Asian energy system. As shown in the draft EIA, because of greenhouse gas emissions from the reservoir, the Rogun HPP will still have a large carbon footprint, similar to that of the current Tajikistan's power system, which means that it will in no way reduce the specific carbon intensity of the country's power sector.

Neighboring countries, on one hand, have great opportunities to develop RE on their territories, and on the other hand, also have plans for rapid development of fossil fuel power plants, often, with the support of international development banks[4]. Therefore, it cannot be overlooked that the contracts for the supply of electricity from the Rogun hydropower plant in the distant future are being used today by politicians and financiers as a "smokescreen" for the short-term provision of needs through the development of fossil fuel generation, which contradicts the objectives of the Paris Agreement.

Thus, the completion of the Rogun HPP with the highest dam will not only fail to result in rapid decarbonization of Central Asian energy systems, but rather, on the contrary, will slow down this process.

[3] https://timesca.com/uzbekistan-aims-to-export-10-15-billion-kwh-of-electricity-to-europe-by-2030/

[4] For example, the World Bank finances a 1,573-MW combined-cycle gas-turbine (CCGT) in Syrdaryo , Uzbekistan https://projects.worldbank.org/en/projects-operations/project-detail/P174323

Flood management. The construction of the "highest dam in the world" as part of the Rogun project is justified by the need to contain the "probable maximum flood", but there is no analysis of alternative measures to reduce flood damage in the ESIA. It appears that the threat of the "probable maximum flood" is simply used to justify the construction of the highest possible dam. Similarly, the creation of a gigantic reservoir is claimed to be justified by its ability to accumulate sediments. However, in reality, successful programs to reduce damage from floods and sediment are always comprehensive and should be considered during the analysis of alternatives - for example, the creation of flood and sediment control structures in the upper reaches of the Vakhsh River, the reduction of erosion in catchment areas, the creation of sufficient flood control capacity at a smaller version of the Rogun hydropower plant, the reconstruction of the Nurek hydropower plant by creating flood control capacity there and/or additional spillways at the hydropower plants of the Vakhsh cascade, etc.

Forced resettlement. By supporting the option of building the highest dam in the world, international development banks are abandoning the crucial objective of minimizing the number of people to be resettled[5]. Meanwhile, most of the 60,000 local residents at risk of involuntary resettlement live above 1,240 meters above sea level, while the Rogun reservoir could be adjusted to reach only lower elevations, including designs with such low elevations that no additional resettlement of local residents would be required. Given the negative aspects of the previous resettlement experience, the extreme sensitivity of the problem for local communities and Tajik society, we are convinced that in order to complete the Rogun HPP project it is necessary to choose options with minimal resettlement, and it is quite realistic to do this now.

Impacts on biodiversity and populations downstream of the Vakhsh HPP Cascade. The Rogun HPP is being created to radically strengthen, extend the service life of, and optimize flow regulation by the Vakhsh HPP cascade, which generates more than half of Tajikistan's electricity. Redistribution of flow of the Vakhsh and Amu Darya rivers by the existing HPP cascade from spring-summer to winter has already caused degradation of floodplain ecosystems (riparian tugay forests), reduction of rare fish populations and worsened conditions for irrigation in dry years. Creating a reservoir of maximum size would triple the potential for such regulation, increasing the risks downstream where the World Heritage site "Tugai forests of the Tigrovaya Balka Nature Reserve" is located, the last populations of endangered sturgeon species live[6], and the fertile plains along the rivers support at least 7 million people whose livelihoods depend entirely on irrigated agriculture in Tajikistan, Uzbekistan, Turkmenistan and Afghanistan. The current international agreements on water allocation were signed at the end of the last century, do not contain clear mechanisms to limit seasonal redistribution of river flows, do not correspond to current conditions and are no longer able to guarantee the reduction of these risks downstream. Choosing the project options with a smaller active volume of the Rogun reservoir will create significantly lower additional risks. Otherwise, **before project financing is approved**, additional binding water resource management agreements should be signed between basin

[5] Avoiding and reducing resettlement is the main objective of the application of the World Bank's ESS-5 socio-environmental standard and similar standards of other development banks regarding forced relocation of people.
[6] For detail on biodiversity impacts see **NGO Letter to Financiers on World Heritage and Biodiversity Impacts of the Rogun HPP** .

countries and enforcement mechanisms established to mitigate risks of water flow disruption for biodiversity and people downstream of the Vakhsh hydropower cascade.

Cost of different RE options. The unit cost of construction of the Rogun HPP (per kilowatt of capacity) is 3-4 times higher than that of SPPs and 2-3 times higher than that of WPPs. As this gap continues to grow, it may be much more efficient to spend most of the $6.4 billion requested in 2024 for the completion of the Rogun HPP[7] to diversify the generation sources of Tajikistan's energy system, rather than to further increase its already near-total dependence on HPPs, which makes the country's energy system highly vulnerable to climate fluctuations. This would ensure the sustainability of generation both within Tajikistan and increase it throughout the region.

Economic viability of the project. An objective analysis of the sensitivity of the project to increases in the cost of HPP construction, increases in the cost differential between HPP and SPP generation, decreases in water flow/availability, and increases in construction time due to various socio-economic and natural factors would undoubtedly show that under each of these very likely changes in the situation, the competitiveness of the high dam options will rapidly decline. The same amount of funding spent on completion of a lower dam with minimized costs, combined with the development of an interconnected SPP using the money saved, would result in greater sustainability and competitiveness of the project, as well as significantly less economic, social and moral damage due to the forced resettlement of local residents from the Rogun reservoir flood zone.

The need to analyze alternatives. In view of the above, the Government of Tajikistan and international financial institutions considering financing the Rogun HPP project must conduct, as part of the finalization of the ESIA materials, a thorough analysis of all possible alternative scenarios for project completion and their social, environmental and economic impacts, including an analysis of their economic viability in comparison with the "high dam" option currently being pursued for the completion of the Rogun HPP construction. Such an approach is a mandatory requirement of the social and environmental policies of most of the banks involved in the project appraisal.

[7] Estimates of the cost of constructing the Rogun hydropower plant have increased by 15% annually in recent years, see https://rogun.exposed/debt

Summary results of consideration of alternative scenarios

In its current form, the Rogun HPP project assumes that all of Tajikistan's capital construction resources are spent on supporting a single megaproject with the construction of the highest dam in the world, while other RE sources are not actively developed. Accelerated growth of RE generation (mainly due to the development of solar energy) is projected only after the completion of the Rogun HPP construction project - see, for example, the "Tajikistan - Country Climate and Development Report" published by the World Bank in November 2024.[8] (Also see its analysis in the Annex)

Is it possible to accelerate and optimize the development of renewable energy in Tajikistan? For example, to start building large-scale solar generation much faster, not after the completion of the "highest dam" of Rogun HPP, but today?

To answer this and other questions, we have selected and analyzed eight different scenarios of RE development, including them in the framework of Rogun HPP project implementation in 2024-2039[9].

According to an International Monetary Fund report published in April 2024, the cost of completing the Rogun HPP in its maximum variant (dam 335 meters high, normal reservoir level 1290 meters above sea level) will be 6.4 billion USD[10] or about 1900 USD per kilowatt of capacity increase (excluding costs incurred before 2024). That is, even without considering the previously spent money, the completion of Rogun HPP to the highest dam level is more expensive than the construction of solar or wind power plants (758 and 1160 USD per kilowatt of installed capacity, respectively[11]).

To demonstrate the need to compare alternatives, in addition to the option with maximum dam height currently proposed in the project, we have considered 7 other scenarios for the completion of the Rogun HPP project, of which 6 scenarios have been previously proposed by engineers and financiers when designing the Rogun HPP project. All scenarios have the same budget: 6.4 billion US dollars.

For each scenario, an approximate estimate of the annual production of the hydropower plant and a rough estimate of the cost of completion are given. In the case of complete decommissioning, the cost includes both the removal of the dam and the creation of surface spillways at downstream dams in the Vakhsh cascade. In other cases, the establishment of the HPP reservoir with the corresponding normal water level (NWL) is assessed (hereafter the scenarios will often be denoted by the NWL figure (e.g., 1290), except for the decommissioning option).

[8] Tajikistan Country Climate and Development Report (CCDR). https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099102424150519451/p50046019e1a6b04b18e6b1b612b3962f41

[9] According to the current WB documentation the filling of Rogun reservoir will take at least 16 years and cannot be completed prior to 2039 (See timetable in the Terms of Reference for Project Management Consultant)

[10] IMF. Request for a twenty-two-month Policy Coordination Instrument (PCI) with the Republic of Tajikistan https://www.imf.org/-/media/Files/Publications/CR/2024/English/1TJKEA2024001.ashx

[11] Hereinafter construction cost and cost of electricity from the summary of the International Agency for Renewable Energy https://www.irena.org/Publications/2024/Sep/Renewable-Power-Generation-Costs-in-2023.

Table 1: Rogun HPP Project Completion Scenarios

№	Scenario, source.	NWL	Active reservoir volume	Reservoir surface area	Power capacity	Output GWh	Approximate cost of completion	Minimal filling period of the reservoir
	Unit.	Meters asl	km^3	km^2	MW		billion dollars.	Years
1	ITEO 2014	1290	10.3	170	3780	14625	6.4	16
2	ITEO 2014	1255	6.45	110	3200	12650	5	13
3	RUSAL 2007	1240	3.98	77	2400	11900	4	11
4	ITEO 2014	1220	3.93	70	2800	10800	4	9
5	WB 2024 Phase 1	1185	0	51	1660	6436	2.44	5
6	Coyne & Bellier and Pöyry 2011	1110	0	12	1200-1800 (1500)	4981	1.5-2	3
7	RwB-recommended option 2024	1070	0	6	800-1200 (1000)	3370	1	2
8	Decommission - WB 2022	N/A	0	0	0	0	1.5	N/A

In each scenario, the amount saved on completion of the Rogun HPP was used to build large-scale solar power plants (Figure 1, lines). The cost of construction was based on the International Renewable Energy Agency (IRENA) data on the average global cost of building a solar power plant in 2023 (758 USD per kilowatt of installed capacity). The highest total capacity (8124 MW) is achieved in scenario 7 (the new scenario proposed by our Coalition, with the completion of the HPP without increasing the current dam height).

For each scenario, approximate total power generation volumes for the next 16 years (the optimistic timeframe for filling the Rogun reservoir as stated in the World Bank project) have been calculated. The scenarios of HPP commissioning and generation are based on data from the 2014 TEAS, the 2023 ESIA, and the 2024 Optimized Master Plan for the Rogun HPP[12]. The construction period of the SPP is 2 years. Commissioning 1,500 MW of capacity per year starting from October 2026. The power generation by the SPP was calculated using the online RE simulator[13] for the climatic conditions in the vicinity of Dushanbe.

The highest cumulative generation over 16 years (200 TWh) is achieved in Scenario 3 with a capacity of 2400 MW for the HPP and 3166 MW for SPPs, but the

[12] See pg. 39, TOR of the Project Management Consultant https://projects.worldbank.org/en/projects-operations/procurement-detail/OP00270949

[13] https://www.renewables.ninja

generation in Scenarios 7, 5 and 4 with a capacity of 1070, 1185, 1220 is only 2-8% less than the maximum. The scenarios with the lowest generation over the first 16 years were Scenario 8 "decommissioning" (125 TWh) and Scenario 1 with NWL 1290 "the highest dam" (144 TWh).

Increasing share of solar generation will improve the reliability of Tajikistan's energy system by reducing its almost-total dependence on a single source. Concerns about intermittency are not relevant for Tajikistan, since the existing HPPs (presently providing 93% of electricity) can operate at night, compensating for the intermittent nature of electricity generation by the SPPs[14].

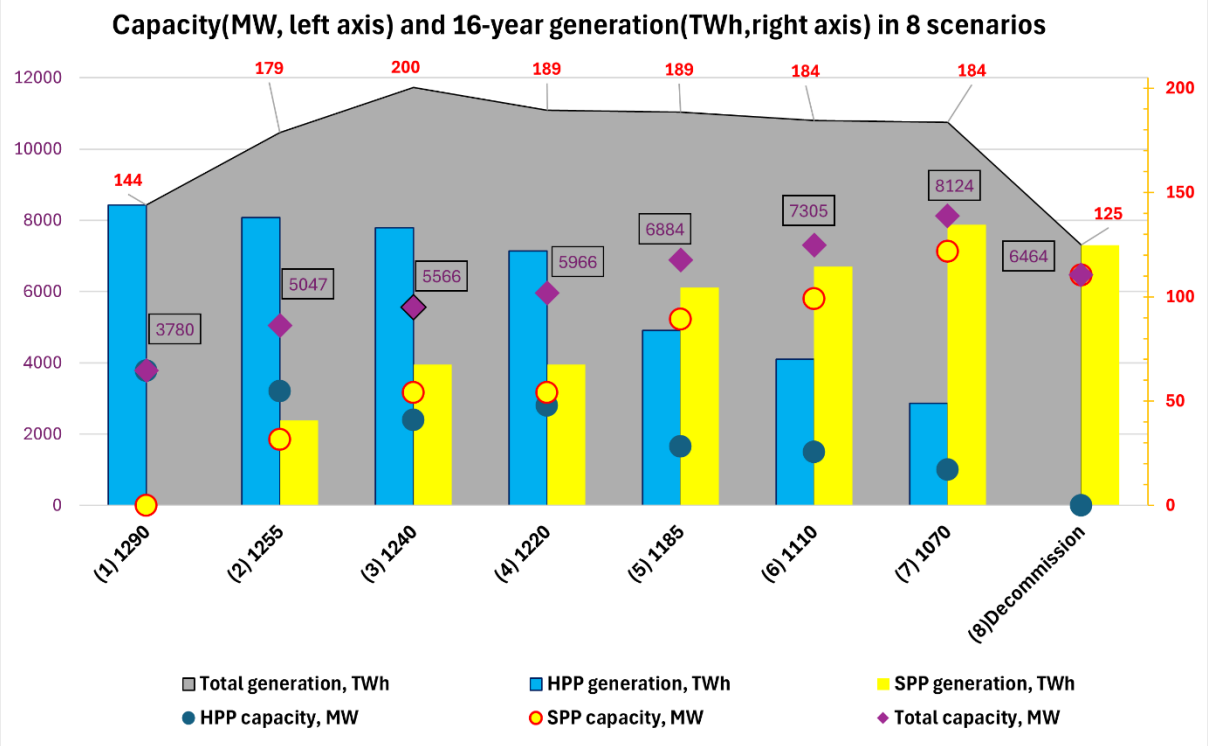


Fig 1. Installed capacity of HPPs and SPPs and their total electricity generation over 16 years (2024-2039) in eight scenarios[15]

Since in recent years Tajikistan has almost fully used its water withdrawal quota in the Amu Darya basin (9.5 km^3 per year) for agriculture, we also considered a situation in which not 0.83 but 0.55 cubic kilometers of water is used annually to fill the Rogun reservoir, which corresponds to the actual unused quota balance on average over the last 6 years. In such a situation, the filling phase would extend by additional 8-9 years, till about 2048-2049 and lead in Scenario #1 to a decrease in total production over 2024-2039 by approximately 15%. In Scenario #2, such loss for 2024-39 is only 2%, and no significant drop in output is expected for the other scenarios.

[14] Jakub Jurasz, Bartłomiej Ciapała. Solar-hydro hybrid power station as a way to smooth power output and increase water retention. // Solar Energy Volume 173, October 2018, Pages 675-690

[15] The output of HPPs in scenarios #6 and #7 may be underestimated by 10-15%, as they may have a higher capacity utilization factor. In these scenarios it is also possible to install 200-300 MW more HPP capacity than we have calculated. This has little effect on the conclusions of the analysis, but if these corrections are made to the model, the total generation in scenarios 6 and 7 will increase by 8-12 TWh over 16 years.

Elimination of winter deficit and electricity cost reduction

The most important reason for the construction of the Rogun hydropower plant is usually cited as getting rid of Tajikistan's winter electricity deficit. This deficit in recent years can be as high as 4 TWh (billions of kilowatt-hours). Given population growth, progress in electrification and increased water scarcity, winter deficit may further increase in the coming decades. We have made an approximate calculation of winter generation for 16 years for each scenario (Figure 2).

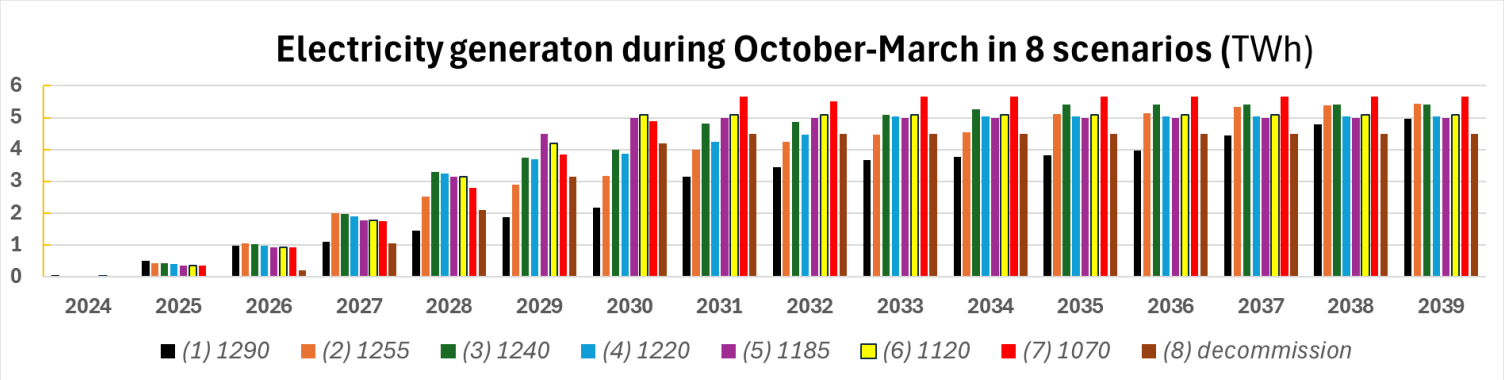


Fig 2. Electricity generation (in TWh) for October-March in 8 different scenarios

Of the eight scenarios, two (Nos. 5 and 6) would overcome the winter deficit as early as 2029. In scenarios Nos. 3-7-8, the deficit will be overcome one year later. The slowest way to reach the 4 TWh milestone is in scenario No. 1 ("the highest dam in the world") with an NWL of 1,290 meters (no solar power added) - approximately by 2036-37. The scenario that will produce the most winter electricity in 16 years is No. 7 (NWL 1070), which from 2031 will produce the most electricity in October-March. It is important to emphasize that the calculation has been done for years of average water availability, whereas in periods with winter runoff deficit, solar-dominated scenarios are likely to be even more reliable in overcoming winter energy deficit than HPP-dominated scenarios.

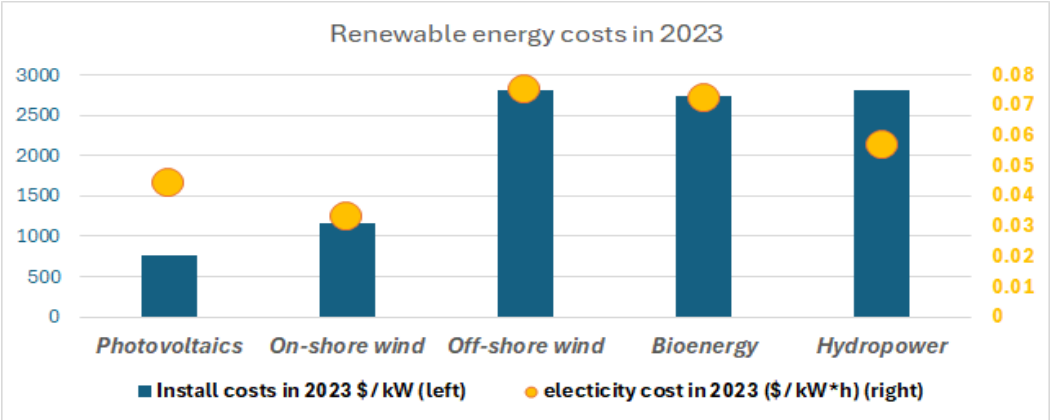


Fig.3 Cost of electricity generation (USD/KWh, right) and construction costs of RE (USD/KW), global average in 2023. Source: International Renewable Energy Agency.

The affordability of electricity for the population of Tajikistan and its competitiveness in the external market depends on its generation cost. Unfortunately, the draft ESIA and other available documents do not contain up-to-date estimates of the cost of electricity generation at the Rogun HPP.

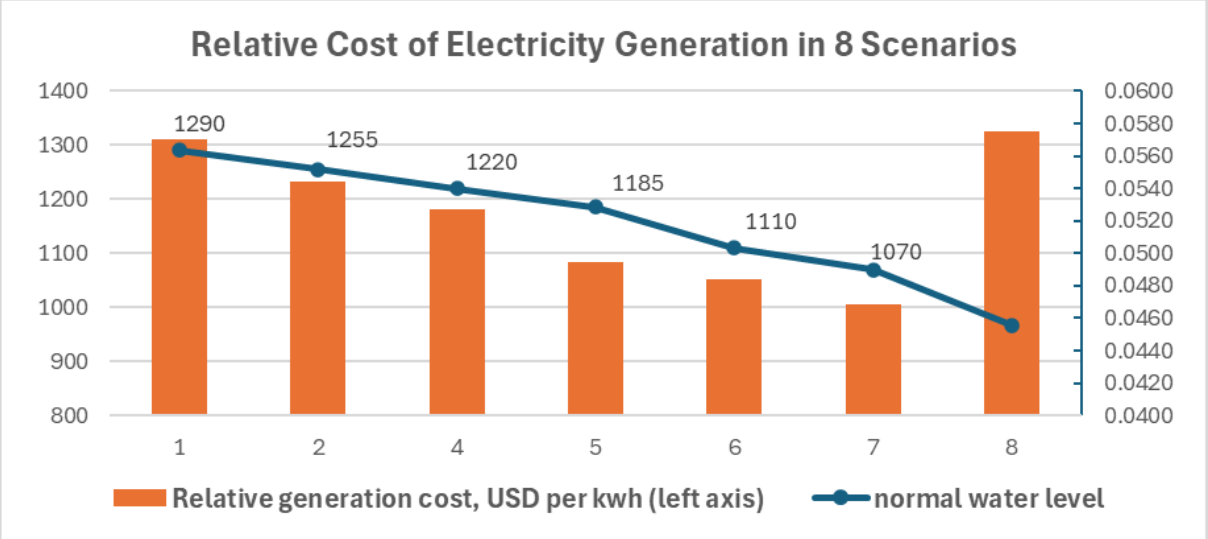


Figure 4. Comparative cost of electricity generated by Rogun HPP and solar farms in different scenarios.

Based on global data for 2023 provided by the International Renewable Energy Agency (Fig.3) we have calculated an approximate ratio of the cost of energy produced in different scenarios (Fig.4). The comparison allows us to assess the potential difference in the cost of energy under different project completion options. The figures reflect the global average cost (LCOE), not the specific cost of the Rogun HPP project. In 2023, the cost of a kilowatt-hour generated by SPPs was 4.4 US cents, while for the HPP it was 30% more - 5.7 US cents[16] (note that the gap is rapidly widening: in 2022, this difference was only 20%, and in 2014, energy from the HPP was four times cheaper than from SPPs: 3.7 cents vs. 17.7 US cents per kWh).

We assume that, given the huge costs already incurred[17] and the requested investments, the cost of Rogun HPP energy will be higher than the world (and regional) average. The published power purchase agreements contain figures that, in our opinion, cannot ensure cost-recovery of Rogun HPP power generation. For example, in the Resolution of the Government of the Republic of Tajikistan No. 595 dated November 2, 2024, the cost of the Rogun HPP's electricity for sale to Kazakhstan is specified at the rate of USD 0.034 per 1 kWh (not including transmission costs) [18]. This

[16] https://www.irena.org/Publications/2024/Sep/Renewable-Power-Generation-Costs-in-2023
[17] Since design began in the 1970s, approximately $5.5 billion has already been spent on the project. https://rogun.exposed/debt
[18] Resolution of the Government of the Republic of Tajikistan No. 595 of November 2, 2024 "On Draft Agreement between the Government of the Republic of Tajikistan and the Government of the Republic of Kazakhstan on cooperation in the field of electric power industry" https://mmih.tj/SEARCH/DocumentView?DocumentId=166863 The agreed price is also, likely, below current export prices: according to media reports in 2021-22 Afghanistan paid Tajikistan 0.0467 USD/kWh https://t.me/sputnikaf/14109

exactly corresponds to the average domestic electricity tariffs in Tajikistan in 2024[19], which according to the IMF and the World Bank is substantially below the recovery cost of electricity production. It should be expected that due to the need to recoup the huge new investments, the recovery cost of energy from the Rogun HPP will be higher than from the currently existing sources of electricity.

Relative generation cost and generation volume in 8 scenarios

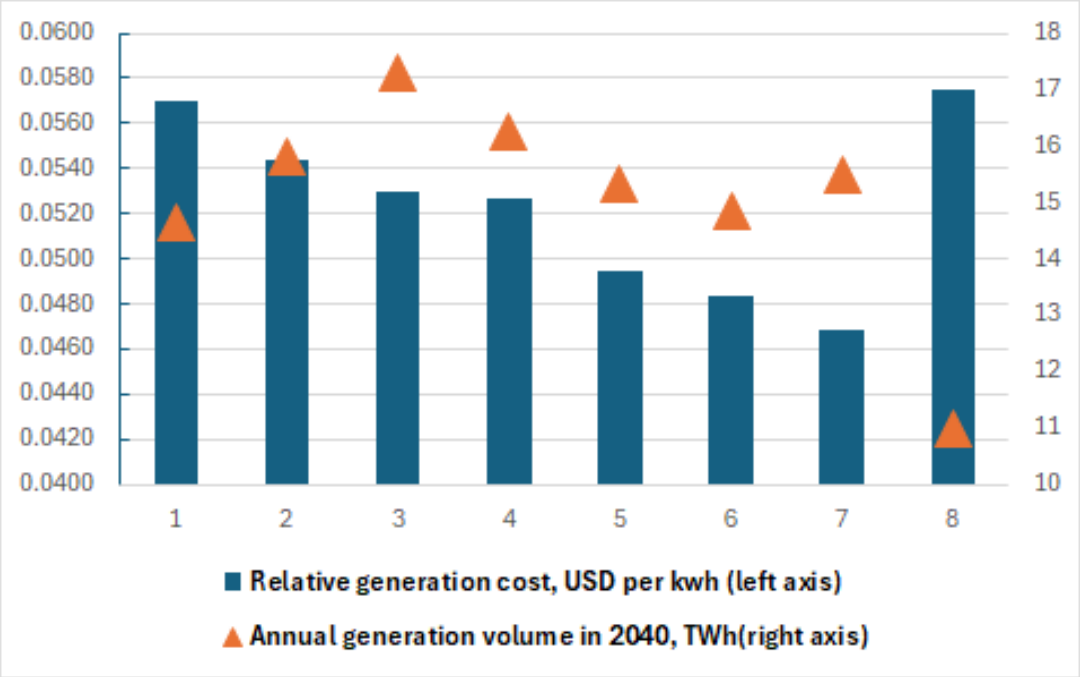


Figure 5. Comparative generation cost (based on 2023 LCOE) and annual power generation in the eight scenarios.

In terms of successful profit generation from exporting electricity to other countries, it is not the scenarios with the highest output that may become more competitive, but those that successfully combine earlier opportunities to export higher volumes of electricity with low production costs. Although Scenario 3 appears to be the leader in terms of annual electricity production, Scenario 7, which produces 11% less electricity, but its production cost is 13% lower, is likely to be preferable (see Figure 5).

[19] https://daryo.uz/ru/2024/07/26/stoimost-elektroenergii

Decarbonization of the Central Asian energy sector

Under the Rogun HPP project, greenhouse gas emissions will increase in proportion to the area of the reservoir (this is the basis of the European Investment Bank's methodology applied in the 2023 ESIA). Knowing the approximate annual output of the HPP at each NWL and reservoir area, we can determine the total GHG emissions for each reservoir option as well as carbon intensity. At the same time, for SPP we take an emissions factor equal to 22 grams of CO_2eq/kWh (by analogy with Italy,[20] where solar radiation is similar to the conditions in Tajikistan). Based on these inputs, we calculated the average carbon intensity for each scenario.

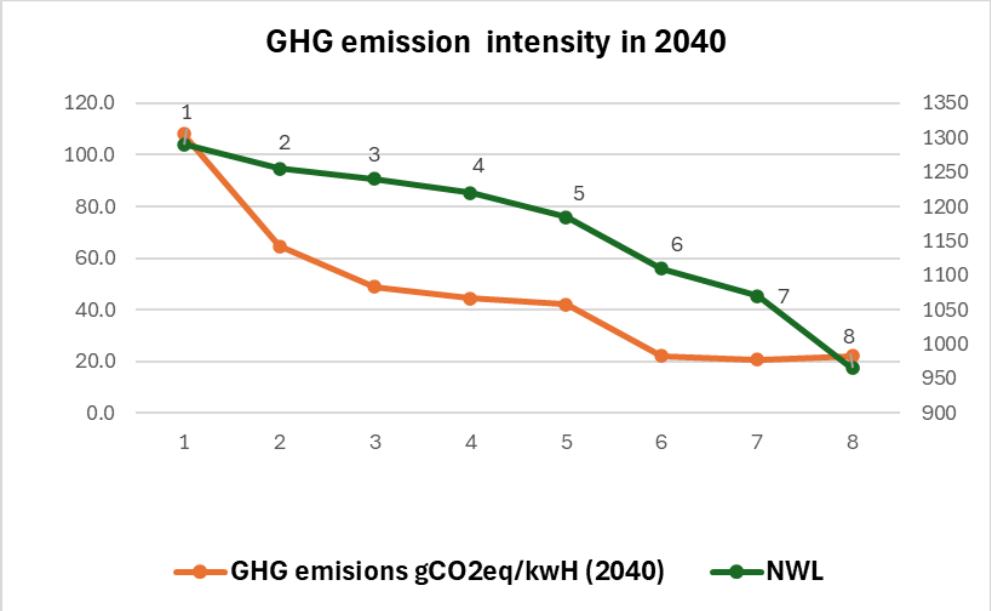


Figure 6. Specific greenhouse gas emissions intensity in scenarios with different NWL (extrapolation of the European Investment Bank methodology)

We see that scenario #1 ("the highest dam in the world") with the largest reservoir (NWL 1290) will have the maximum annual GHG emissions from all scenarios. According to calculations based on the methodology adopted in the ESIA, in case of full completion of the Rogun HPP, emissions from its reservoir (thus not counting emissions from construction) will increase the total emissions of the contemporary electricity sector of Tajikistan by 60%. At the same time, the production of similar amounts of energy by SPPs will increase the total emissions of the energy system by only 10-15%, (and that calculation includes emissions from the entire production cycle).

Thus, the scenarios with dominant SPP participation have the lowest emissions and smallest carbon footprint.

It is also important to consider that the less carbon-intensive scenarios 3-4-5-6-7 assume the achievement of annual generation of 14 billion kWh in 7-9 years, while the

[20] https://iea-pvps.org/key-topics/environmental-life-cycle-assessment-of-passivated-emitter-and-rear-contact-perc-photovoltaic-module-technology/

scenario with the "highest dam in the world" expects this level only in at least 15-16 years, which makes it ineffective in view of the urgency of decarbonization of the Central Asia's energy sector.

In addition, the commissioning of SPP capacity can be accelerated by increasing the number of simultaneously built plants, while the commissioning of a large HPP has several risk factors that can seriously delay the project completion date (Rogun HPP has been under construction since the 1980s and the project was less than 30% complete as of early 2024). That is why we are convinced that the scenarios of Rogun HPP project completion with predominantly solar generation are the most consistent with the goals and objectives of the Paris Agreement.

Minimizing resettlement and other social and environmental impacts

The low dam scenarios, assuming no new resettlement of residents from the flood zone, are preferable from the point of view of minimizing economic, social, and moral damage, and are more consistent with the requirements of the World Bank's social and environmental standards. This approach will save 37,000 to 52,000 people from forced resettlement, as well as save significant compensation\resettlelment costs (see Figure 7A and https://rogun.exposed/resettlement).

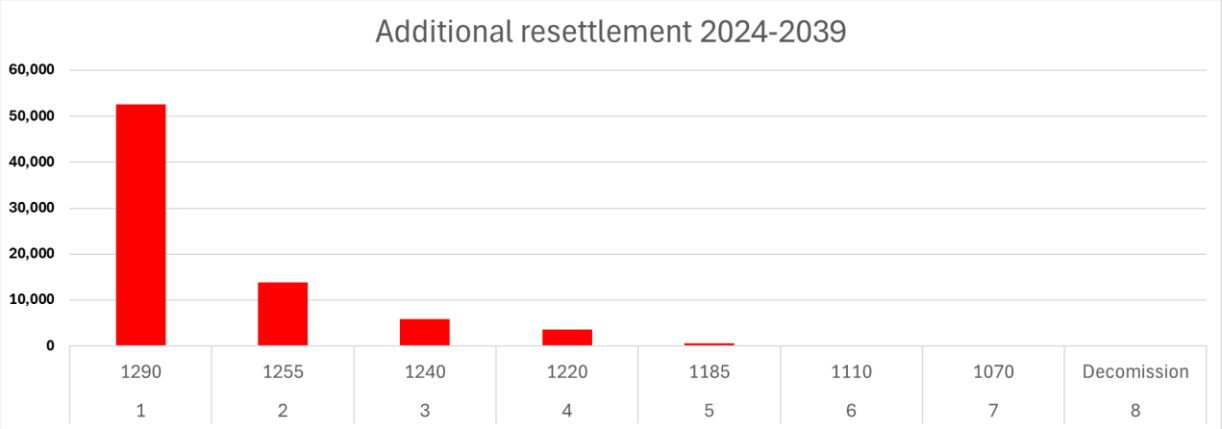


Figure 7A. Involuntary resettlement[21]. (About 8,000 people have been resettled as of early 2024, which is not reflected in this graph.).

The most inhumane and risky scenarios are those with the NWL of the Rogun HPP reservoir higher than 1240 meters.

We have seen earlier that some of the scenarios with lower dam height considered here are also the fastest and most efficient way to end winter electricity shortages and produce electricity at a price most affordable to the population. Both factors are of high social importance, as electricity shortages and high prices push those in poverty

[21] In the EIA documents the number of people to be resettled is vaguely estimated as "up to 60 thousand". Since there is no information on the place of residence of ten thousand of them, we assigned them to scenario #1, where the largest forced resettlement was assumed earlier.

to increase their use of coal and firewood, with large negative environmental, climatic and health impacts. Also, increases in electricity tariffs stimulate the rise of inflation[22] and a fall in living standards, so the cost of electricity generated is the most important factor in ensuring the well-being of the poor.

The high-dam scenarios also carry the greatest risks of competition for water with the inhabitants of the lower reaches of the Vakhsh-Amudarya rivers and are also fraught with negative impacts on biodiversity. In particular, the greater the active volume (regulation capacity) of the Vakhsh cascade reservoirs, the greater the risks of degradation of the UNESCO World Natural Heritage site "Tugai Forests of Tigrovaya Balka Reserve", the ecosystems of which are entirely dependent on the flow regime of the Vakhsh River.[23] (On Figure 7B that risk is shown as a variable correlated with the total active volume of the Vakhsh cascade HPP reservoirs in cubic kilometers.)[24]

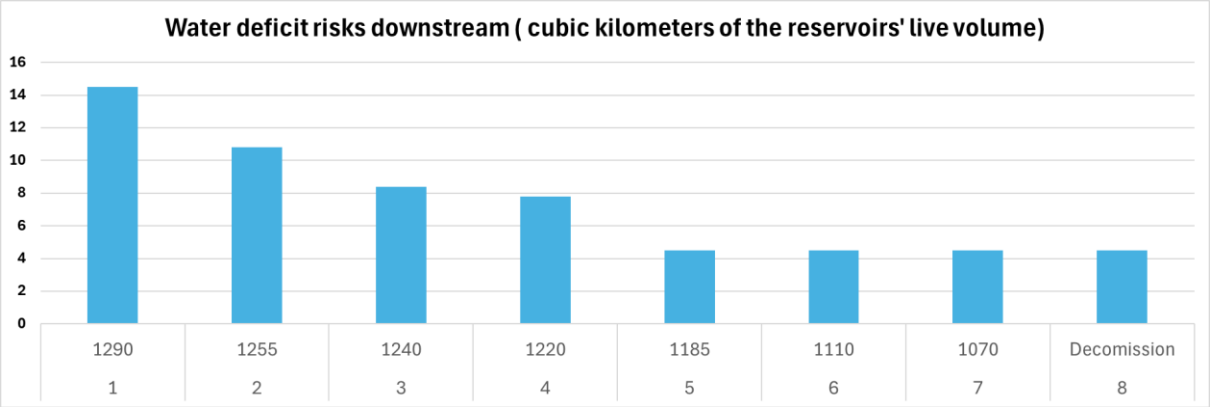


Figure 7B. The risk of negative impacts downstream correlated with the total active volume of the Vakhsh hydropower cascade.

Thus, from the point of view of improving the welfare of the local population and respect for human rights, biodiversity conservation, as well as ensuring conditions for sustainable and balanced development of the country and the region, the most effective development strategy for Tajikistan is not to build the highest dam in the world, but to complete the Rogun HPP with a relatively low dam and simultaneously create large capacities of other renewable energy sources.

[22] World Bank. July 2024. Tajikistan Economic Update https://thedocs.worldbank.org/en/doc/32cdc98fe3e6e0120eb15b05aa2b9faa-0080062024/original/Tajikistan-Economic-Update-Summer-2024-en.pdf

[23] https://rogun.exposed/biodiversity

[24] Such correlation between downstream impacts and dam-height (reservoir volume) is inevitable in scenarios in which Rogun HPP is built with a sole objective to maximize and optimize electricity production (as implied by the current World Bank-sponsored project). If the objective is changed to incorporate priorities of providing ecosystem services and supporting irrigation in downstream areas, then much of the negative impacts may be mitigated through developing binding water resource management agreements with riparian countries. Presently Tajikistan refuses to develop such agreements and the project objectives clearly prioritize electricity generation.

Scenarios ranking in terms of usefulness/safety for Central Asian development

Based on the above-described benefit/risk indicators for each scenario, we ranked the scenarios for each indicator from 1 to 8, taking into account the difference between the numerical values which reflect degree of impacts[25] (Fig.8). Rank 1 means the lowest utility/safety and rank 8 means the highest. We also calculated the average value among the six indicators considered. The results are summarized in Table 2 and Figure 8.

Table 2. Scenario ranking

Scenario	*NWL*	*Reduction of GHG emissions*	*Avoiding resettle-ment*	*Risks of downstream water scarcity*	*The speed of getting rid of the winter deficit*	*Electricity generation cost*	*Output over 16 years*	*Average scenario rating*
1	***1290***	*1*	*1*	*1*	*1*	*1*	*3*	***1***
2	***1255***	*2*	*3*	*2*	*6*	*3*	*5*	***4***
3	***1240***	*4*	*5*	*3*	*7*	*4*	*8*	***5***
4	***1220***	*4*	*6*	*3*	*6*	*4*	*7*	***5***
5	***1185***	*5*	*7*	*5*	*8*	*6*	*7*	***6***
6	***1110***	*7*	*8*	*5*	*8*	*7*	*6*	***7***
7	***1070***	*7*	*8*	*5*	*7*	*8*	*6*	***7***
8	***Decommission***	*8*	*8*	*6*	*7*	*1*	*1*	***5***

Scenario 1 (NWL 1290- "the highest dam in the world"**)** is the worst of the options for completion of Rogun HPP by most criteria.

It is likely that the prolonged completion of the Rogun hydropower project with "the highest dam in the world", on which, according to the World Bank, the government annually uses up to 80% of the state budget funds used for infrastructure development in Tajikistan[26], will hold back the commissioning of cheaper RE technologies, the development period for which is much shorter, thus significantly slowing down and making it more expensive to achieve climate goals in Central Asia.

Scenarios 6 (NWL 1110) and 7 (NWL 1070) with a lower dam and prevalence of solar generation are favorable according to most of the indicators considered and are subject to lower risks under changing external conditions.

[25] As indicated earlier for the "*Risks of downstream water scarcity" we assume that the Rogun HPP is created to maximise and optimize electricity production and no binding agreements are signed with riparians to ensure risk reduction for biodiversity and local communities downstream. Tajikistan refused to commit to environmental flow releases to preserve floodplain ecosystems and to prioritize irrigation needs in downstream countries under drought conditions. Otherwise scenarios 1-2-3-4 would have different risk ranking for this group of impacts.*

[26] *Tajikistan Infrastructure Governance Assessment.* Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/099120723131516850/P1770900047d8c07e09ef4022cafdf277e1

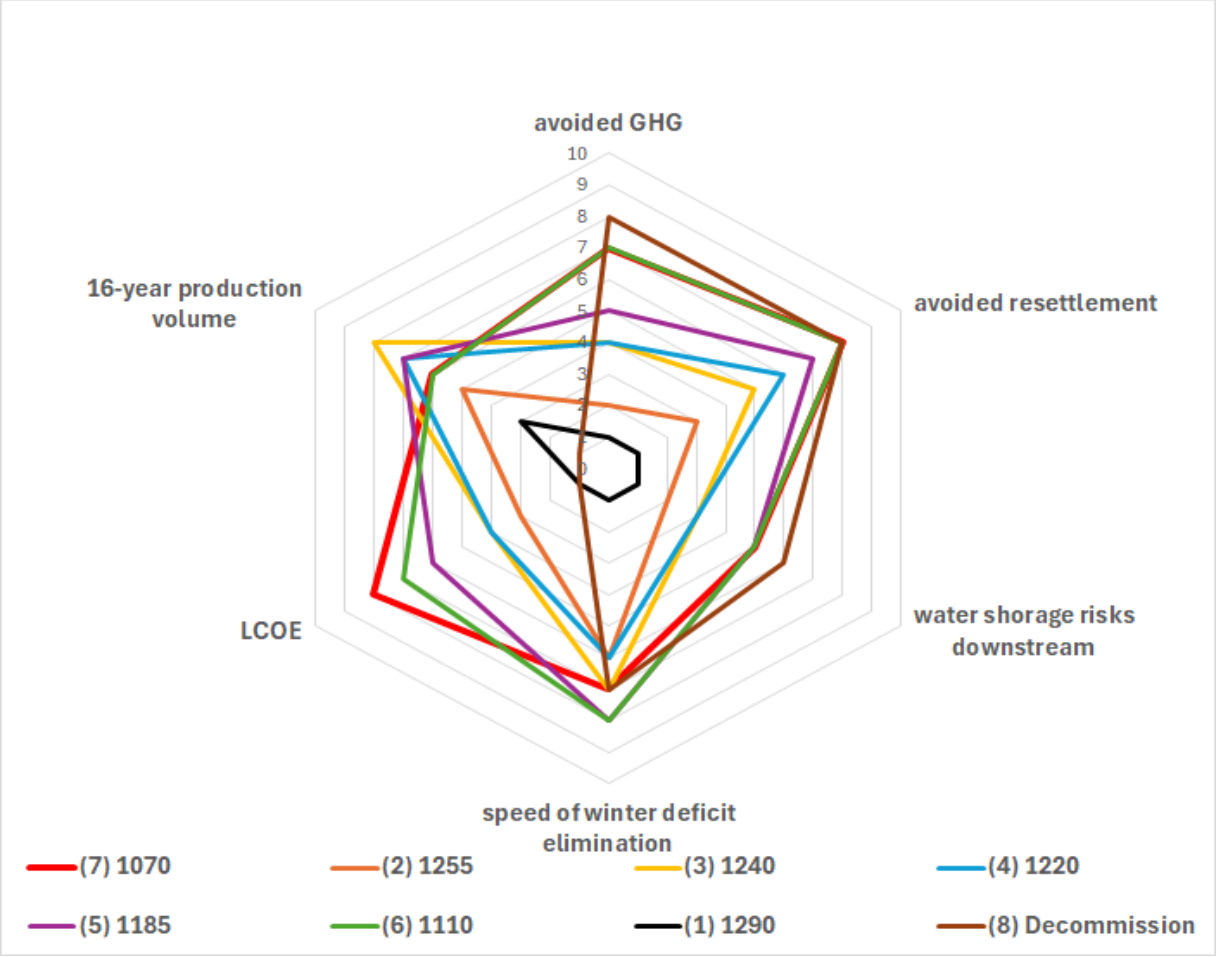


Figure 8. Multifactor evaluation during scenario ranking (the smaller the contour area, the less useful and more dangerous the scenario).

When financing the construction of a network of solar (and wind) power plants, these plans are easily adaptable to changes in the economic situation and improvements in energy production and storage technologies. This flexibility is another decisive advantage over the scenario of a single giant hydropower plant, which requires firm guarantees of completion in the distant future.

Commissioning solar and wind power plants is the fastest and most effective way to reduce greenhouse gas emissions in the region. The existing hydropower capacities of Tajikistan and Kyrgyzstan (5.8 and 3.6 GW respectively[27]) could be used as maneuvering capacity in the overall Central Asian power system, facilitating rapid commissioning of other RE.

If the Rogun HPP project is hastily financed without objective consideration of alternatives and measures to mitigate negative impacts, it will not bring the expected socio-economic benefits, but to the contrary - will lead to severe irreparable socio-environmental consequences and will significantly slow down the decarbonization of Central Asian energy systems.

[27] https://public.tableau.com/app/profile/irena.resource/viz/IRENARETimeSeries/Charts

Recommendations

1. As part of the finalization of the ESIA of the Rogun HPP Project, conduct an analysis of alternatives taking into account the current situation and knowledge, including options such as the completion of the hydropower plant with a reservoir normal water level of 1070, 1110 and 1185 meters above sea level. Consider the issues raised in this document when analyzing alternatives.
2. Incorporate into the ESIA of the Rogun HPP Project assessment of the impact of different options combining the completion of the HPP and construction of solar and wind capacity.
3. As important criteria for selecting the best option, consider factors such as:
    - the number of additional people to be resettled,
    - specific greenhouse gas emissions,
    - speed of commissioning of capacities capable of meeting winter demand
    - cost of produced energy and its price for the population
    - competitiveness of generated electricity in the markets of foreign countries and the region as a whole,
    - vulnerability to water scarcity and potential risks of impacts on ecosystems and population downstream of the Vakhsh HPP cascade.

4. Fully incorporate the World Bank's Environmental and Social Framework requirements into the analysis of alternatives, in particular those arising from the environmental and social standards ESS-1, ESS-3, ESS-4, ESS-5 and ESS-6 (see https://rogun.exposed/non-compliance for details).
5. Consider the financial sensitivity of different options for project completion to different speed of increase in the cost of completion (Rogun HPP in the last 15 years is characterized by growth of the total cost of the project by 15% per year, while for the global hydropower industry the average annual growth of those costs has been 10%).
6. Ensure full-fledged international/riparian public consultations of the finalized draft ESIA report, including on the section "Analysis of Alternatives".
7. Do not make a decision on project financing until the analysis of alternatives and the optimized plan for completion of Rogun HPP construction and development of Tajikistan's energy system are completed and public consultations on these documents\plans are held with all stakeholders.

APPENDIX: Optimizing Tajikistan's Low Carbon Electricity Development Plans

Extremely valuable new evidence of the need to consider alternative scenarios for the Rogun HPP project is the World Bank's "**Tajikistan: Country Climate and Development Report"**[28] (November 2024).

The report analyzes the "Low Carbon Development Scenario" as the best development alternative, with a very informative graph for the power sector (Figure 1). In the first 15 years (2019-2034), the graph shows a relatively slow growth of 22 TWh in electricity generation, mainly as a result of the full commissioning of the Rogun hydropower plant (the report erroneously states 2037 rather than 2039 as the date of full commissioning of the hydropower plant). The logic of the statement is clear: in the first 15 years, all the country's resources are spent on supporting one single HPP megaproject, and other sources of RE are developed either only moderately (solar) or not at all (wind). Then, from 2035 to 2050, there is an accelerated growth of RE generation due to the development of solar energy, which increases generation by 50 TWh. It is easy to calculate that the World Bank assumes annual commissioning of at least 1.5 GW of SPP capacity after 2030.

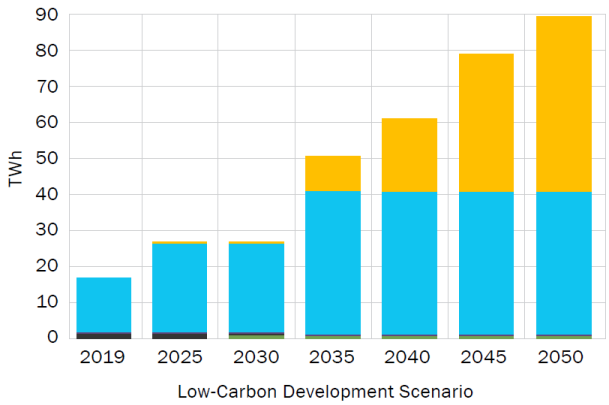


Figure 1. Graph of electricity production in Tajikistan (in Terawatt-hours).
Source: World Bank, "Tajikistan: Country Climate and Development Report" 2024.

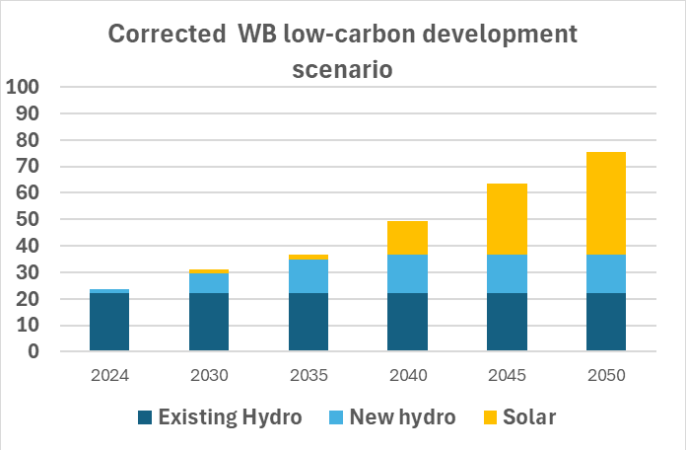
A legitimate question arises: "Is it possible to accelerate and optimize the development of green energy in Tajikistan? For example, can we start building solar faster not from 2034, but already today?

We have corrected the optimistic scenario created by the World Bank to take into account the actual contemporary power generation volume, the current planned timeframe for filling the Rogun reservoir, and the country's lack of funds to invest in other RE while the Rogun HPP is under construction. If RE development proceeds at the WB-declared pace (1.5 GW of SPP installed annually), by 2050 the energy system

[28] Tajikistan Country Climate and Development Report (CCDR).
https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099102424150519451/p50046019e1a6b04b18e6b1b612b3962f41

will generate 75 TWh (see Figure 1A) rather than 90 TWh as predicted by the World Bank (see Figure 1).

We further optimize this plan based on the assumption that the completion of the Rogun HPP project proceeds according to our proposed scenario #7 (NWL 1070 - completion of the HPP with the dam height at the current level). It will take 2-3 years. In parallel, following the World Bank proposal, 1,500 MW of solar plants are commissioned annually throughout the period up to 2050 (Figure 1B).



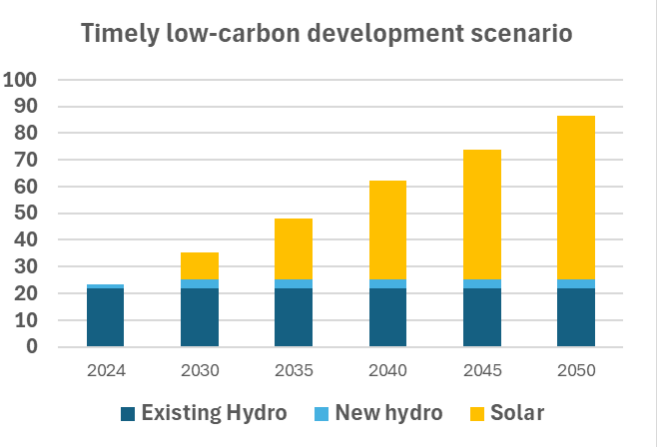


Figure 1A: Corrected World Bank plan (left) and Figure 1B: Our optimization of Tajikistan's Low Carbon Development Scenario (right). (The original World Bank timeline (Fig 1) shows the full commissioning of the Rogun hydropower plant (14 TWh) earlier than planned, and the current scale of power generation and pace of its development is somewhat exaggerated).

As a result, in the optimized scenario, the generation of all power plants in Tajikistan in 2030 is 4 TWh more than in the World Bank scenario, and from 2035 on the gap widens to 10 TWh annually (15%). Over the entire period from 2025 to 2050, our optimized scenario generates about 200 TWh more electricity than the World Bank's adjusted low-carbon scenario. This is equivalent to nine years of generation from the current Tajikistan power system.

In our optimized scenario, by 2035 Tajikistan will have a substantial surplus of cheap electricity in both winter and summer, allowing it to enter the regional renewable energy market earlier. Thus, starting large-scale solar generation in Tajikistan now will significantly accelerate the low-carbon development of the country and the region.